

Li transport modeling based on recent DIII-D DiMES experimental results

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Objective

- Understand what caused the initial core Li penetration event in DIII-D shot 105511, how the core Li accumulation was sustained and why this resulted in a locked mode followed by a disruption.

Approach

- Analyze DIII-D experimental data to understand the sequence of events leading to the core Li induced disruption in shot 105511.
- Use the Monte Carlo Impurity (MCI) transport model with b2.5 background plasma solutions and experimental data to:
 - determine how changes in the divertor and SOL properties affect the onset and transport of Li during the initiation of the enhanced core Li accumulation phase.
 - assess what causes an increase in core Li accumulation following the initial injection event.

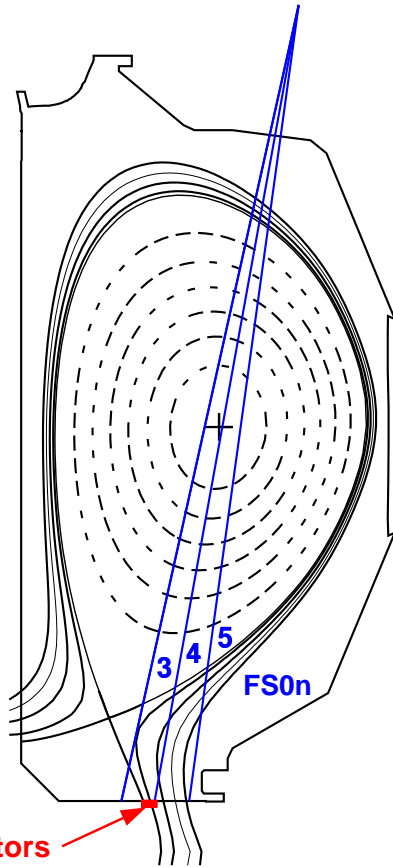
Status and preliminary results

- The experimental data shows a dramatic increase in the core Li penetration at about the same time the SOL current recovers from a large transient non-axisymmetric event.
- Preliminary modeling indicates that standard Li ion transport mechanisms can not explain the sudden increase in core Li.
- A rapid neutral Li ballistic injection mechanism, similar to that of a slow moving killer pellet, is consistent with the data.

Non-axisymmetric SOL currents are initiated at about the same time the core Li increases

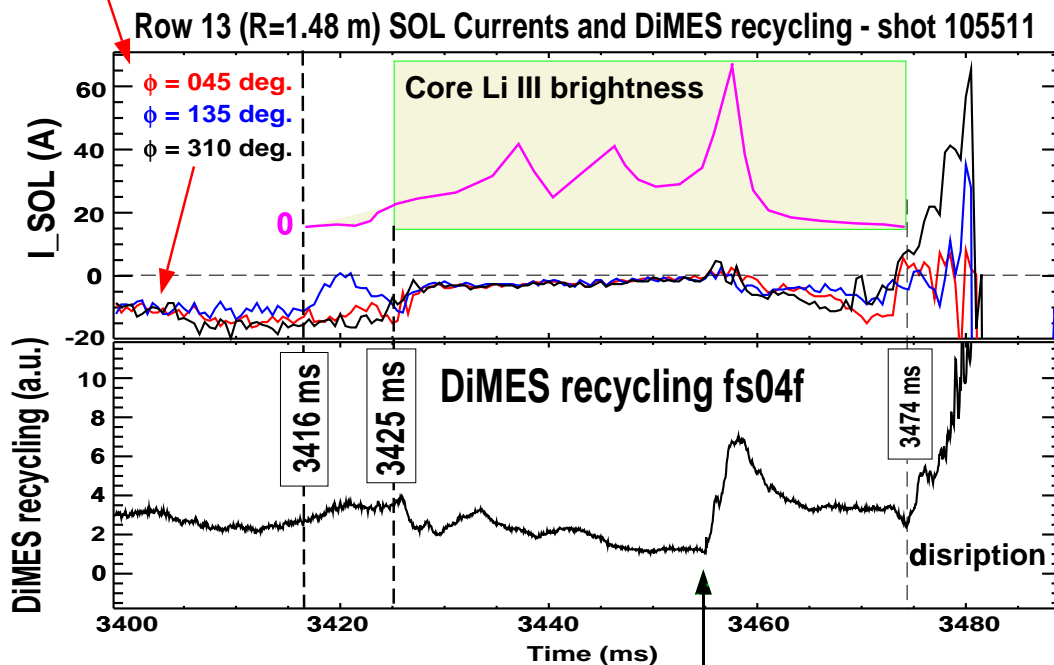
DIII-D shot 105511

time	3425.00
chi**2	22.731
Rout(m)	1.706
a(m)	0.567
elong	1.678
V (m**3)	16.409
A (m**2)	1.579
q1	8.085
q95	3.769
dsep(m)	0.081
BT(0)(T)	-2.005
gapin(m)	0.123
gapout(m)	0.081
dRsep	-0.400



- An increase in the core Li content changes the profiles and triggers a locked mode which leads to a disruption.
- Numerical modeling is needed to determine if the initial increase in core Li is related to a change in the Li ion transport or an SOL current driven neutral Li injection event.

DiMES Probe and row 13 TCA monitors



Locked mode initiated by core profile changes caused by Li influx

SOL currents appear to be responsible for the first core Li penetration event but can not explain the sustained core Li increase later in the shot

Shot 105511 observations

- The Li surface temperature increases steadily until about 3416 ms with no indication of an enhancement in the neutral Li release rate or core Li penetration probability.
- Between 3416 and 3420 ms the SOL current flowing out of a divertor target plate located 15 degrees toroidally upstream from the Li sample drops to about zero while the the current at other toroidal locations remains constant at about -15 A/tile.
- The local SOL current near the Li sample attempts to recover and the core Li level begins to increase.
- By 3425 ms the SOL current at all toroidal locations in row 13 (the row with the Li sample) decay slowly to zero while the core Li increases at a steady rate.
- The core Li increases more rapidly between 3430 and 3435 ms while the SOL currents decay to less than -2 A/tile.

How does the Li get into the core plasma?

- The rapid increase in core Li at approximately 3425 ms appears be related to SOL currents acting on a liquid Li surface causing the injection of a singel 5-6 mm diameter Li blob at about 20 m/s into the core plasma.
- After 3420 ms the SOL currents decay to about zero while the core Li content is increasing. This phase in Li core penetration can not be explained by MHD forces acting on the remaining Li sample in the DiMES probe.

The core Li increase can best be explained by the injection of a single large, slow-moving, blob followed by a 10-15 ms core ablation phase

Monte Carlo transport modeling status

- Fluid background solutions are available from b2.5 (Owen and Maingi) for shot 105508 at 3900 ms.
- More information is needed about the properties of the plasma during and following the SOL current asymmetry event in shot 105511 and about the neutral Li source after 3415 ms.

Penetration of Li due a single blob injection event

$$\lambda_{\text{pen}} = \frac{N_{\text{blob}} V_{\text{blob}}}{dN/dt} \quad \left\{ \begin{array}{l} N_{\text{blob}} = 5e21 \text{ particles (measured)} \\ V_{\text{blob}} = 15\text{-}20 \text{ m/s (measured)} \end{array} \right.$$

$$dN/dt = 2.1e15 n_e^{0.333} T_e^{1.64} r_{\text{blob}}^{1.333} M_{\text{Li}}^{-0.333} \quad \Leftarrow \text{Li blob ablation rate}$$

$$\left. \begin{array}{l} \lambda_{\text{pen}}^{\text{div}} \approx 150 \text{ m} \\ \lambda_{\text{pen}}^{\text{core}} \approx 0.15 \text{ m} \end{array} \right\} \begin{array}{l} (n_e = 1e13 \text{ cm}^{-3}, T_e = 20 \text{ eV}, r_{\text{blob}} = 3 \text{ mm}) \\ (n_e = 3e13 \text{ cm}^{-3}, T_e = 1 \text{ keV}, r_{\text{blob}} = 3 \text{ mm}) \end{array}$$

Conclusions

- The initial core Li penetration event seen in shot 105511 most likely resulted from a ballistic, pellet-like, injection event driven by SOL currents acting on the surface of the Li sample.
- The sustained increase in core Li following the Li blob injection at 3425 ms is consistent with core ablation rate calculations due to a 5-6 mm diameter blob with a velocity of 20 m/s.